Comparing Arctic Sea Ice Kinematics from Satellite Remote Sensing Data to ECCO2 Model Results

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Motivation (1)

Sea ice deformation in the Arctic climate system:

- Divergence creates open water → new ice growth in winter
- Convergence creates pressure ridges → thicker ice
- Controls heat and moisture fluxes to the atmosphere and brine rejection to the ocean
- Alters the air and water drag coefficients

➔ Correct modeling of sea ice kinematics important for sea ice mass balance and ocean – air energy fluxes

Motivation (2)

Sea ice model evaluation with ice deformation fields:

- Mean sea ice velocity field is behaving similar to a turbulent fluid → predicted correctly by simple models [Rampal et al., 2009].
- Comparisons with first order mean velocity fields therefore **not sufficient.** Second order **sea ice deformation should be used**.

Tuning the ECCO2 sea ice model:

- Traditional Hibler-type ice model with elliptical yield curve
  - Sea ice deformation field is not represented correctly in all details
  - But it is widely used in climate research.

➔ Tune model to best represent observed sea ice kinematics

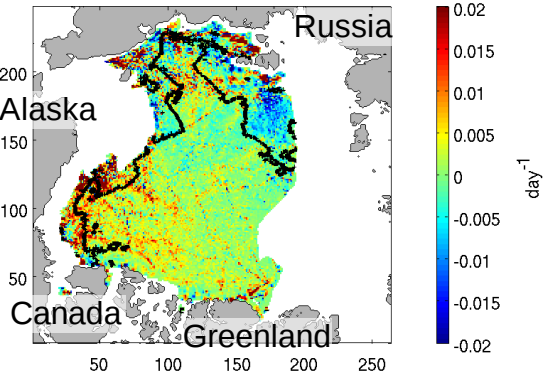
Outline

Comparison of observed RADARSAT Geophysical Processor System (RGPS) SAR sea ice deformation fields to ECCO2 MITgcm model results

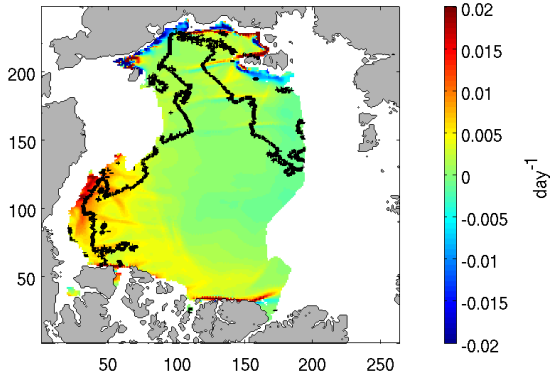
- Part 1: Dependence on model resolution
- Part 2: Dependence on model sea ice strength formulation

RGPS and ECCO2 Sea Ice Deformation

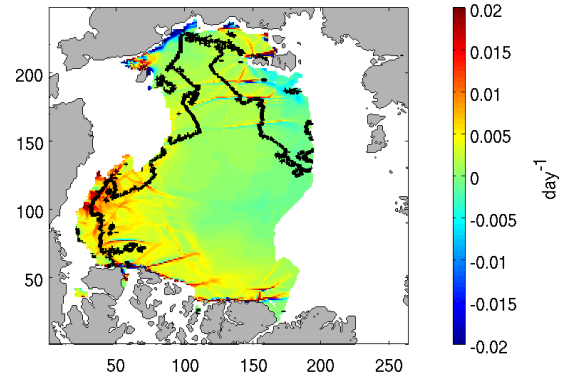
RGPS divergence



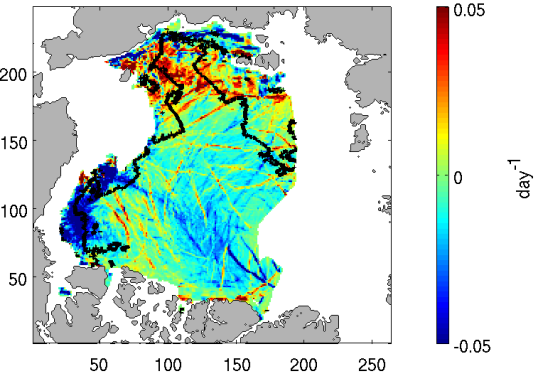
18km divergence



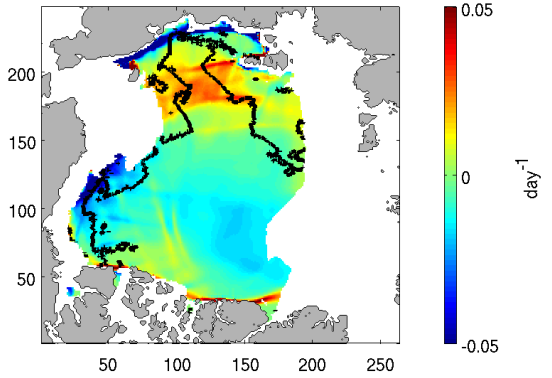
9km divergence



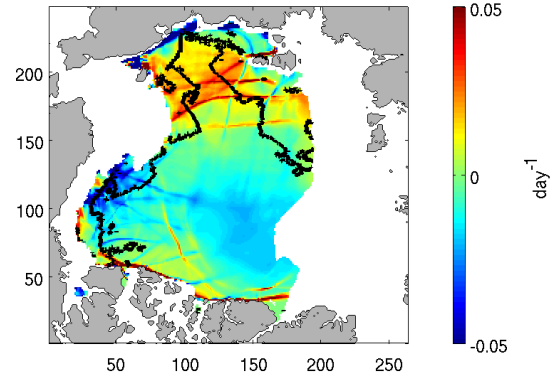
RGPS vorticity



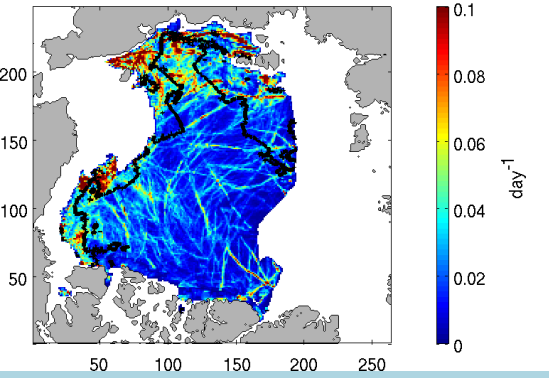
18km vorticity



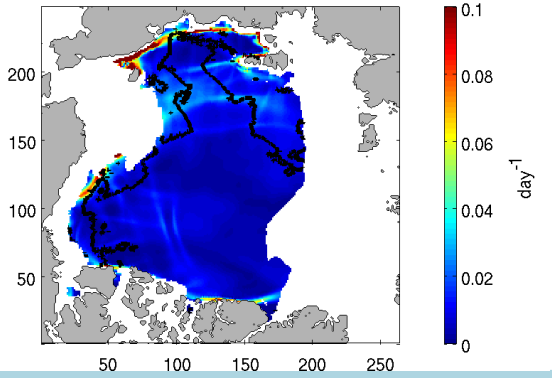
9km vorticity



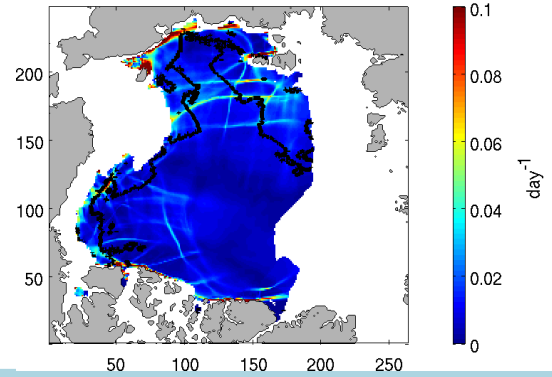
RGPS shear



18km shear



9km shear



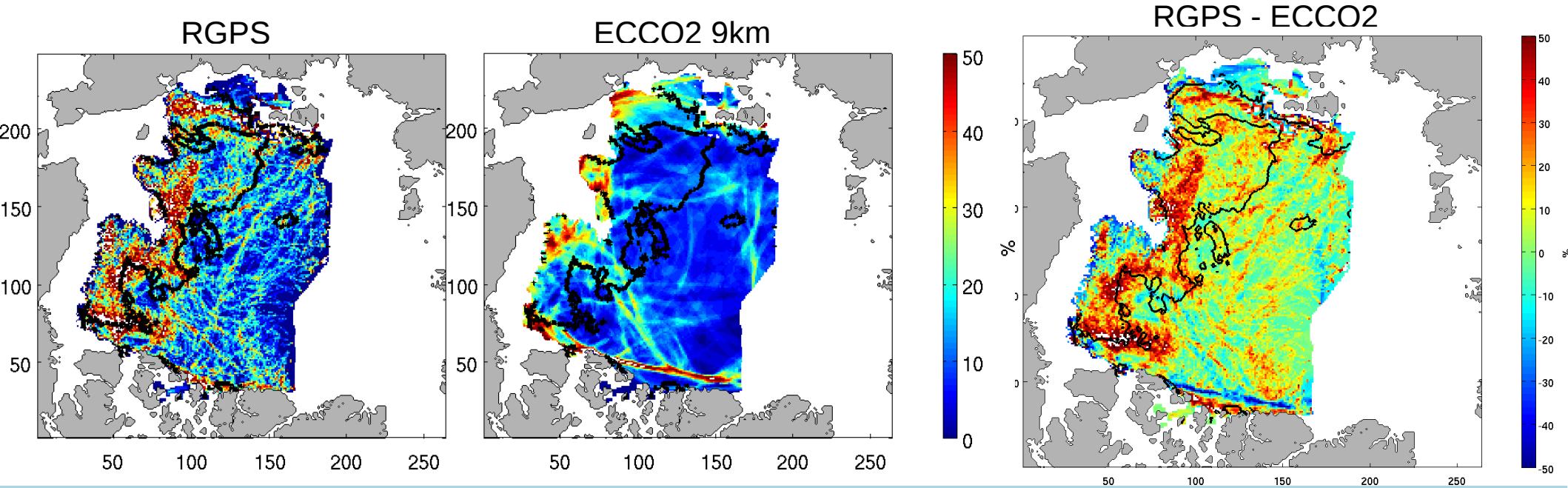
November 1997

black line: perennial ice

Fractional Number of Deformed Cells

- The absolute amount of deformation variables divergence, vorticity, and shear depends on the spatial scale over which they are measured (e.g. Stern and Lindsay, 2009).
- Using the fractional number of times a grid cell was deformed (div > 0.02/day OR shear > 0.03/day) during a given period for comparisons.

Nov./Dec. 1998



Ice Pressure (Strength)

Sea ice pressure formulation: $P_{max} = P^* h^n e^{[C^*(1-a)]}$

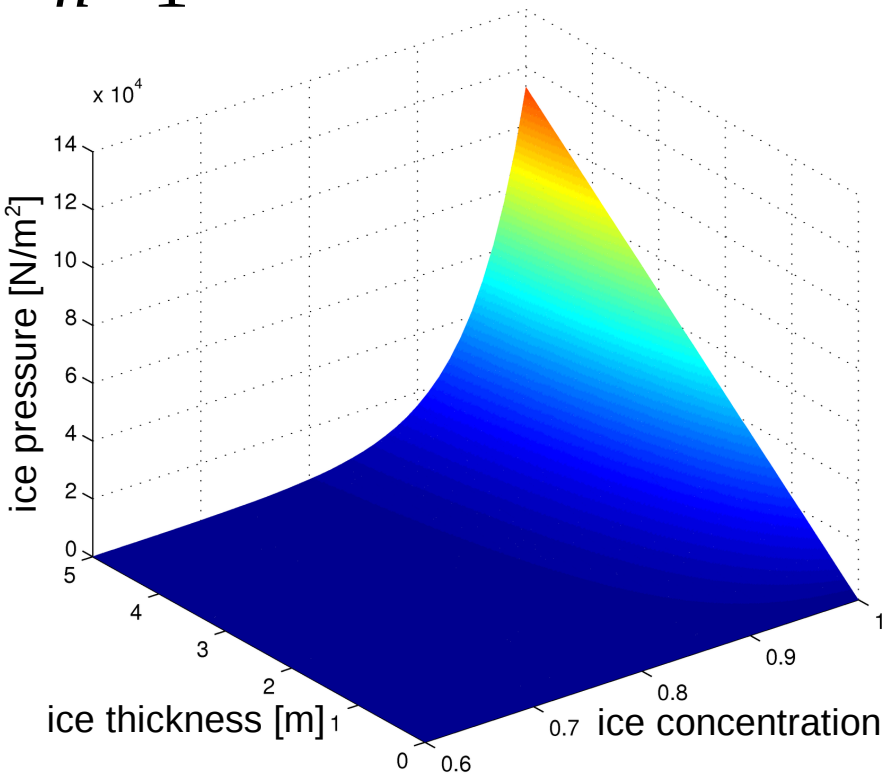
h: ice thickness; $C^* = -20$

a: ice concentration

Control parametrization:

$P^* = 22640$

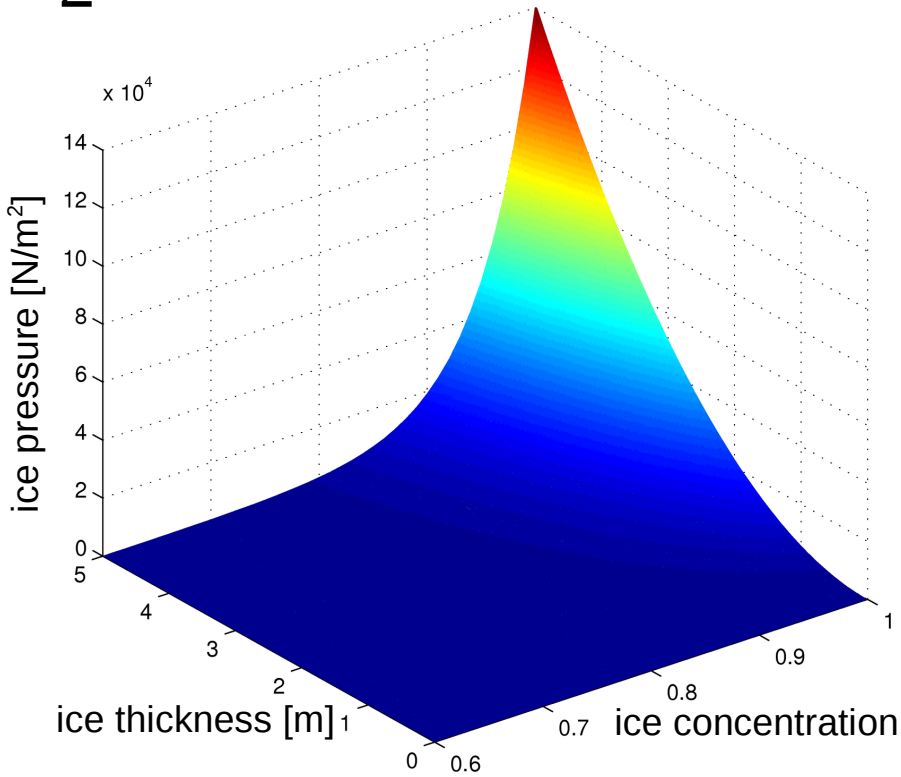
$n = 1$



Test parametrization:

$P^* = 5660$

$n = 2$



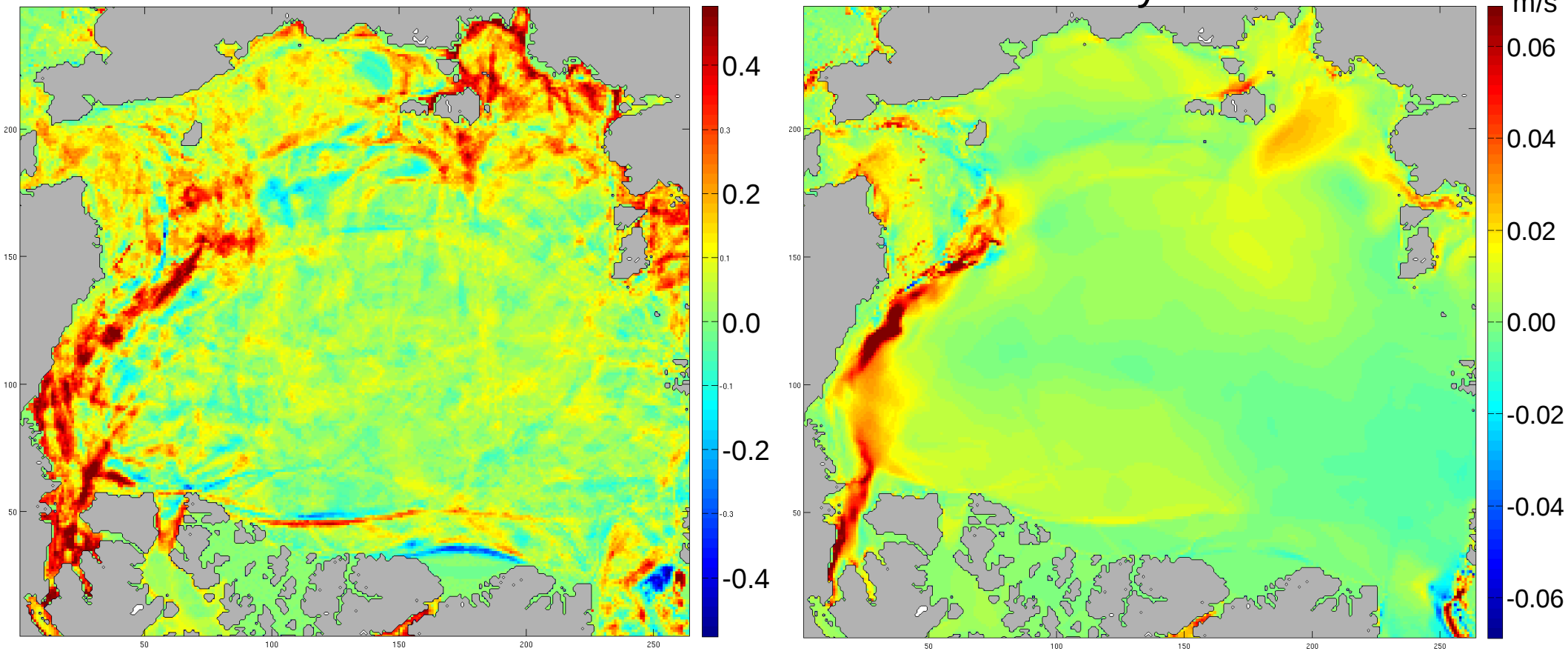
Test – Control Difference

- Difference in fract. number of deformed cells and velocity: Test – Control ice strength formulation

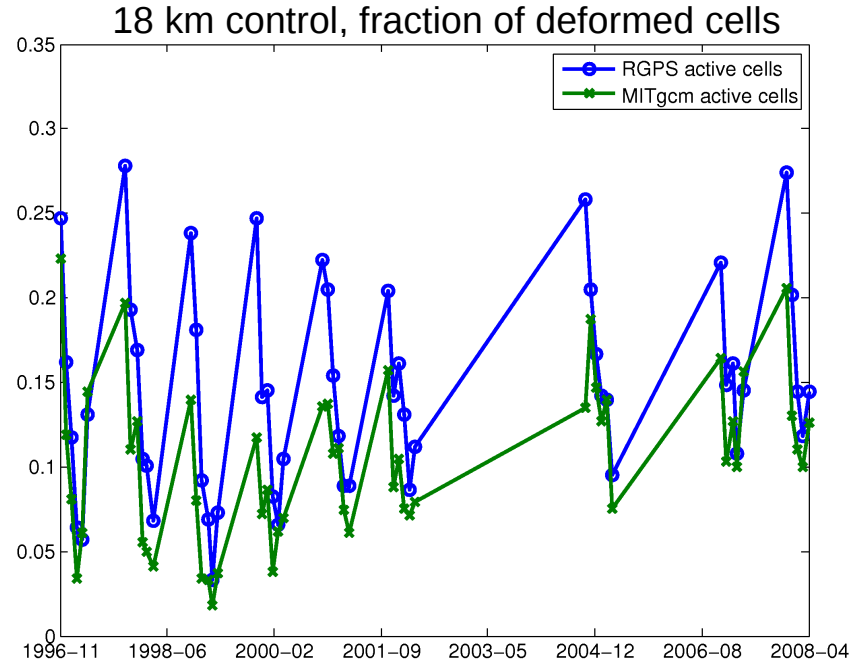
➔ More deformed cells, especially in seasonal ice zone.

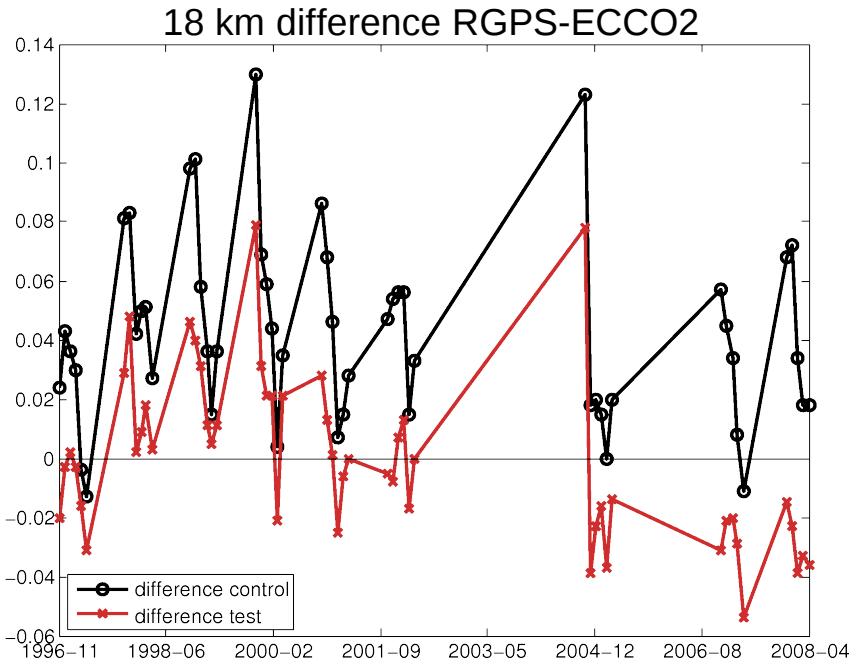
➔ higher ice velocity in seasonal ice zone.

deformed cells difference Nov./Dec. 1997 velocity difference



Time Series of Deformed Cells





Time series of deformed cells for winter months 1996-2008.

Difference RGPS–ECCO2

	mean [%]			st. dev.	corr.
	all	MY	FY	all	all
18km control	4.2	2.9	7.0	8.3	0.86
18km test	0.0	0.4	1.0	5.5	0.89
9km control	4.3	2.3	7.5	8.3	0.87
9km test	-0.1	-0.6	0.7	5.9	0.90

all: 52 months
MY, FY: 24 months

➔ New ice pressure formulation improves ice deformation distribution independent of model resolution.

Conclusions

- Observed RGPS data and ECCO2 model results show similar large scale sea ice deformation patterns but small scale deformations, like fracture zones, are very different.
- Increase in model resolution produces more and stronger confined ice deformation features, the general deformation distribution and amplitude, however, does not change significantly $\rightarrow$ model physics seem to be inadequate for correct reproduction of all aspects of sea ice kinematics.
- A change of the model sea ice strength formulation away from the linear dependence on ice thickness can improve the modeled sea ice deformation distribution compared to observations.